DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Washington, DC 20004-2901

September 13, 2011

Mr. David Huizenga
Acting Assistant Secretary for Environmental Management
U. S. Department of Energy
1000 Independence Avenue, SW
Washington, DC 20585-0113

Dear Mr. Huizenga:

The staff of the Defense Nuclear Facilities Safety Board (Board) conducted a review of the hazards and controls associated with the anhydrous ammonia system at the Waste Treatment and Immobilization Plant (WTP) at the Hanford Site. Ammonia is stored at the WTP site in the Balance of Facilities (BOF) as a pressurized liquid in two outdoor 6,000-gallon storage vessels that will be refilled periodically by tanker trucks. The Board does not believe that the controls for the ammonia system, as currently designed, adequately protect workers or facilities at WTP. More specifically, the Board is concerned that workers in the main control room may be unable to perform safety-related operations in the event of an emergency at WTP.

The Board's staff evaluated the existing controls for the ammonia system against requirements in Title 10 Code of Federal Regulations Part 851, *Worker Safety and Health Program*, and Department of Energy Order 420.1B, *Facility Safety,* and found the following deficiencies:

- *Control room habitability*—The design of the ventilation system for the main control room is insufficient to protect workers following an ammonia release. The Board's staff found that there is a risk that ammonia concentrations will increase above levels considered "immediately" dangerous to life and health as the result of a large ammonia release from the storage vessels or a tanker truck accident.

- *Seismic event*—The controls for a seismic event are inadequate to protect facility workers in the event of an earthquake that exceeds Seismic Category III (SC-III) design criteria. The impact of such an earthquake could cause a large ammonia release from the SC-III storage vessels and result in multiple fatalities among workers located outdoors during the accident or any personnel evacuated outdoors.

- *Transportation accident*—Controls for a tanker truck spill are inadequate to protect facility workers. A transportation accident would have effects similar to those of a rupture of the storage vessels from a seismic event; however, the workers might have insufficient notification that this accident had occurred.

- *Facility interactions*—The current safety-related control set is insufficiently protective of other facilities. The Board identified unanalyzed hazards caused by interactions between BOF and the remainder of WTP, including impacts from an ammonia release on safety-class structures, systems, and components in other facilities. Examples include the potential for vapor cloud explosions, as well as damage to the emergency generators due to high ammonia concentrations and subsequent loss of emergency power across the site.

Therefore, pursuant to 42 U.S.C. § 2286b(d), the Board requests a report within 60 days of receipt of this letter that addresses ammonia release and spills, including (1) a plan for performing a hazards analysis addressing interactions between BOF and other facilities; (2) an evaluation of the safety margin of the ventilation system for the main control room and, if necessary, a plan for redesigning the system; and (3) an evaluation of the adequacy of the controls for seismic events and transportation accidents that addresses the issues identified in the enclosed report.

Sincerely,

Peter S. Winokur, Ph.D.
Chairman

Enclosure

c: Mr. Scott L. Samuelson
Ms. Mari-Jo Campagnone

DEFENSE NUCLEAR FACILITIES SAFETY BOARD

Staff Issue Report

July 1, 2011

MEMORANDUM FOR: T. J. Dwyer, Technical Director

COPIES: Board Members

FROM: E. Gorrepati, R. Oberreuter, A. Poloski

SUBJECT: Chemical Vapor Releases, Waste Treatment and Immobilization Plant

This report documents the results of a review by the staff of the Defense Nuclear Facilities Safety Board (Board) of the hazards and controls associated with the anhydrous ammonia system at the Waste Treatment and Immobilization Plant (WTP) at the Hanford Site. Staff members E. Gorrepati, R. Oberreuter, A. Poloski, and S. Stokes conducted this review on April 27, 2011, with representatives of the Department of Energy (DOE) Office of River Protection (ORP) and the WTP design authority, Bechtel National, Incorporated (BNI).

Background. The off-gas systems for the High Level Waste Facility and Low Activity Waste Facility melters at WTP are designed to control emissions of oxides of nitrogen (NO_x) with a selective catalytic reduction operation utilizing anhydrous ammonia. Anhydrous ammonia will be stored as a pressurized liquid in two outdoor 6,000-gallon storage vessels. These vessels will be refilled periodically by tanker trucks. Given the hazardous nature of ammonia, BNI analyzed accidents involving the sudden release of a large quantity of ammonia. BNI's initial analyses modeled ammonia releases as plumes; however, a more recent BNI calculation models ammonia releases as a "puff" followed by a steady plume. BNI's puff-plume model is consistent with the methodology in Nuclear Regulatory Commission (NRC) Regulatory Guide 1.78, *Evaluating the Habitability of a Nuclear Power Plant Control Room during a Postulated Hazardous Chemical Release.*

BNI analysts used the NRC methodology to model releases of hazardous chemicals, including ammonia, from storage and transportation accidents. The staff's review focused on the ammonia hazard because of the large quantity stored at the site. BNI analysts evaluated the unmitigated consequences of chemical releases in the main control room (MCR), an adjoining annex to the Pretreatment Facility (PTF). Based on the current safety strategy, operators in the MCR are required to perform safety-related functions in response to emergency situations. To protect these workers from an ammonia release, BNI has designed a mitigative control—an in-line carbon bed to adsorb released ammonia as it is drawn into the MCR ventilation system. This control was developed based on the earlier plume-only analysis, which predicted a lower demand on the MCR ventilation system than the puff-plume analysis.

Some key requirements applicable to the ammonia hazards present at WTP include those from Title 10 Code of Federal Regulations Part 851 (10 CFR Part 851), *Worker Safety and Health Program*, and DOE Order 420.1B, *Facility Safety*. For example:

- DOE Order 420.1B, Chapter IV, §3.a(1): "Facility SSCs [structures, systems, and components] must be designed, constructed, and operated by the contractors to withstand NPH [natural phenomena hazards] and ensure (a) confinement of hazardous materials; (b) protection of occupants of the facility, as well as members of the public; (c) continued operation of essential facilities; and (d) protection of government property."

- 10 CFR Part 851.10: "With respect to a covered workplace for which a contractor is responsible, the contractor must: (1) Provide a place of employment that is free from recognized hazards that are causing or have the potential to cause death or serious physical harm to workers."

- 10 CFR Part 851.21: "Contractors must establish procedures to identify existing and potential workplace hazards and assess the risk of associated workers [sic] injury and illness. Procedures must include methods to: ...(8) Consider interaction between workplace hazards and other hazards such as radiological hazards."

Findings. The Board's staff reviewed the following: (1) assumptions and input parameters BNI used in the modeling; (2) the equations and calculations that comprise the puff-plume model; (3) BNI's analysis of the model results of ammonia concentrations at the MCR ventilation system intake; (4) and BNI's design of the MCR ventilation system to mitigate the ammonia concentrations within the MCR breathing space. The staff found the equations and calculations of the puff-plume model to be correct and appropriate for this application. We also found the selection of carbon beds to mitigate the ammonia hazard to workers inside the MCR to be a reasonable control for the design of the MCR ventilation system.

In addition to our review activities described above, we performed a sensitivity analysis that varied the input parameters used in BNI's puff-plume modeling, as well as assumptions regarding performance of the carbon beds. This analysis was designed to evaluate the degree of conservatism in BNI's MCR ventilation system design (which is based on the plume-only model) and to determine the overall risks faced by WTP workers in the MCR. In addition, the staff considered impacts of an ammonia accident to workers in other parts of the WTP site, as well as to other facilities across the site. The staff's review revealed that, given a puff-plume release of ammonia: (1) some of the assumptions in BNI's puff-plume analysis are not reasonably conservative, lack strong technical foundation, or are not valid for all plant conditions; (2) the MCR ventilation system may therefore be under designed; and (3) BNI's control strategy fails to satisfy requirements of 10 CFR Part 851 and DOE Order 420.1B for adequately protecting workers and facilities across the WTP site.

Control Room Habitability—Following a design basis accident, the plant operators in the MCR will be required to perform safety-class and safety-significant actions for which there are no automatic controls. For example, following a seismic event, MCR operators must activate the Safe Shutdown Interlock to isolate the PTF from non-emergency power, steam, and air systems, among other functions. If MCR operators fail to manually activate the Safe Shutdown Interlock, a radiological release may result. The current WTP safety strategy requires that habitability within the MCR be maintained such that workers can actively perform their credited safety-related actions. BNI's puff-plume analysis shows that in accidents involving ammonia storage and transport, the existing carbon beds in the MCR ventilation system would approach 90 percent of their ammonia loading design capacity. The staff's primary concerns with the available design margin are that some of BNI's assumptions and input parameters are not reasonably conservative, lack strong technical foundation, or are not valid for all plant conditions. The carbon beds would therefore be subject to higher ammonia loadings than those predicted in BNI's analysis.

There are various credible scenarios under which the carbon beds would exceed 100 percent of their design capacity or significantly reduce the efficacy of the system, potentially resulting in ammonia exposures to facility workers above levels considered immediately dangerous to life or health (IDLH)—300 ppm as defined by the National Institute for Occupational Safety and Health. Examples of assumptions and input parameters in BNI's analysis that are of concern to the staff include:

- Breakthrough of the carbon bed—BNI's analysts assumed that the efficiency of ammonia removal is the same for all ammonia concentrations. However, the ability of the carbon bed to adsorb ammonia will decrease at very high challenge concentrations, resulting in breakthrough (i.e., significant concentration of ammonia passing through the bed without being adsorbed). The project did not analyze for the occurrence of ammonia breakthrough.

- Reduced atmospheric wind speed—The wind speed used in BNI's analysis is based on an hourly wind speed average. This method is appropriate for long-duration applications, but not for designing systems to accommodate short-duration, high-concentration events. For example, NRC Regulatory Guide 1.145, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, provides the following guidance for short-duration events: "If releases associated with a postulated event are estimated to occur in a period of less than 20 minutes, the applicability of these models [for determining atmospheric dispersion] should be evaluated on a case-by-case basis." BNI's analysis shows that the duration of an ammonia puff passing over the MCR ventilation intake is on the order of five minutes. Using hourly average data would potentially overestimate wind speeds and underestimate the ammonia loading on the carbon beds, as predicted concentrations are highly sensitive to wind speeds. When designing the MCR ventilation system carbon beds, BNI did not select a wind speed based on the short duration of an ammonia release event.

- A carbon bed that is initially loaded with contaminants—BNI's analysts assumed that the carbon bed initially has 100 percent capacity (i.e., it is not loaded with any contaminants) at the beginning of the puff release. However, the carbon bed will be exposed routinely to atmospheric contaminants that will accumulate during normal operation. In fact, preliminary vendor estimates are that the carbon bed will need to be replaced every six months due to contaminant loading from background emissions. The project did not consider initial loading of contaminants when determining the required design capacity of the carbon bed. If more than approximately 10 percent of the bed is loaded with contaminants at the time of an ammonia accident, BNI's analysis indicates that the bed would exceed its capacity.

Based on the above potential issues, the staff completed a sensitivity analysis to determine the impact of changes in these assumptions on ammonia concentrations in the MCR. The results of the staff's analysis show that the design of the MCR's ventilation system is not always protective of facility workers. Small changes in modeling assumptions resulted in ammonia loadings that exceeded the design capacity of the carbon beds, thereby allowing concentrations inside the MCR to exceed IDLH levels within a few minutes. The staff concludes that the current design of the ventilation system for the MCR is inadequate to ensure the safety of the MCR operators.

Seismic Event—BNI designed the anhydrous ammonia storage vessels to a Seismic Category III (SC-III) rating. The vessels could rupture and release a large quantity of ammonia in the event of an earthquake that exceeded SC-III design criteria (other WTP facilities have been designed to more stringent SC-I design criteria, e.g., PTF). Additionally, in response to a seismic event, the emergency response for WTP is to evacuate some WTP facilities. This action will potentially expose evacuating workers to any resultant ammonia release. BNI's puff-plume release calculation shows that facility workers outdoors at the time of the earthquake and in the path of the ammonia puff would be exposed to concentrations of ammonia vapor that could result in multiple fatalities. The Board's staff believes that this outcome demonstrates inadequate protection of facility workers as prescribed in 10 CFR 851 and DOE Order 420.1B, and that additional controls are necessary to ensure that workers are protected from an ammonia release caused by a seismic event. In addition, DOE Guide 420.1-2 states, "When safety analyses determine that local confinement of high-hazard materials is required for worker safety, PC-3 [performance category three] designation may be appropriate for the SSCs involved". This suggests that the ammonia tanks could be constructed to a higher seismic category rating (SC-I, equivalent to PC-3), thereby minimizing the potential of an ammonia leak resulting from an earthquake.

Transportation Accident—BNI's puff-plume release calculation demonstrates that transportation accidents involving ammonia tanker trucks will also result in large, high-concentration plumes and exposures to workers similar to those resulting from a seismically induced ammonia release. The ammonia storage vessels have nearby detectors to indicate a leak and initiate response actions; however, there is no similar notification mechanism in the case of a transportation accident, as such an accident can occur anywhere along the roadways at the WTP site. The Board's staff believes further controls (e.g., additional ammonia detectors, safe routes for worker evacuation and/or locations at which to shelter in place, personal protective equipment) are necessary to ensure that workers are protected from a transportation accident involving an ammonia tanker truck.

Facility Interactions—Currently, BNI analysts perform hazards analyses for individual facilities and have not performed such analyses for hazards that occur in one facility and impact another. The Board's staff identified several potential interactions between an ammonia release from the ammonia storage vessels, located in the WTP Balance of Facilities (BOF), and other WTP facilities. For example, a puff-plume release of ammonia can produce a detonable gas mixture with the potential to result in a vapor cloud explosion. Depending on the location and magnitude of the explosion, safety-related SSCs in other facilities could be damaged, thereby being prevented from performing their designated safety function(s).

A second example involves the potential impact of an ammonia release on operation of the emergency generators. The emergency generators provide emergency power to facilities in the WTP complex. In the Preliminary Documented Safety Analysis (PDSA) for the BOF, BNI considers plumes of ammonia and carbon dioxide to be external hazards that could compromise safety-class equipment in the emergency generator facility. The plan for addressing these hazards is to locate the ventilation intakes for the emergency generator facility at a sufficient elevation to prevent the gas from causing the generators to fail by displacing oxygen. However, the PDSA still refers to a 2010 calculation that models plumes originating at the storage vessels; a new calculation from July 2011 uses the puff-plume release model and indicates that the existing intake stack height may not sufficiently protect the emergency generators. In addition, the 2011 analysis does not include the potential for the ammonia to cause mechanical damage to components inside the emergency generator facility. The staff believes a reevaluation of the design of the emergency generator facility based on the 2011 calculation is necessary to ensure the emergency generators are adequately protected from a large chemical release.

Conclusion. The Board's staff believes the current controls for the ammonia system are inadequate to protect WTP workers or facilities for the following reasons:

- *Control room habitability*—The design of the ventilation system for the MCR is not sufficiently robust to protect workers adequately. The analysis performed by the Board's staff shows that ammonia concentrations could increase above IDLH levels as the result of a large release from the ammonia storage vessels or tanker truck.

- *Seismic event*—The controls for a seismic event are inadequate to protect facility workers if the ground motion from an earthquake is in excess of what was assumed in the design of the ammonia storage vessels. The impact of increased ground motion could cause a large ammonia release that could result in multiple fatalities among WTP workers located outdoors at the time of the event or any personnel evacuated outdoors.

- *Transportation accident*—Controls for a truck spill are inadequate to protect facility workers. A transportation accident would have effects similar to those of a release from the storage vessels; however, workers might have insufficient notification that this accident had occurred to prevent potentially lethal consequences.

- *Facility interactions*—The current control set is insufficiently protective of other facilities. BNI's analysts did not analyze hazards occurring in BOF to determine potential impacts on the remainder of WTP facilities, including the impacts of an ammonia release or other hazards on safety-class SSCs in other facilities.